Session 9: Tungsten, tungsten alloys, and advanced steels and Technology and qualification of plasma-facing components, Friday, May 23 2025, 9:00-11:15
Location: lecture room

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Overview of Advanced Plasma-Facing Materials Testing for Fusion Pilot Plants at DIII-D

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A total of 17 novel plasma-facing materials (PFMs) from 8 institutions have been successfully tested at the DIII-D National Fusion Facility as a part of the ongoing, two-year FPP Candidate Materials Thrust. This effort coordinates exposure and down-selection of promising PFMs through testing at DIII-D in an integrated, reactor-like environment. The first year of experiments were completed across 3.5 run days utilizing the Divertor Materials Evaluation System (DiMES). The materials included varieties of tungsten (W) (alloys, fibers, dispersoids), W capillary porous structures (CPS) with liquid lithium (Li), thermal spray W coatings, ultra-high temperature ceramics (UHTCs) and silicon carbides (SiC) (CVD, coatings, fibers), analyzed pre- and post-experiment via SEM, EDS, and confocal microscopy. Repeatable reference discharges were developed to ensure uniformity between experiments, including a new strike-point rastering/sweeping scenario to provide more uniform heat/particle flux across DiMES during ELMing H-mode discharges: $q_{(,inter-ELM)}$ ≈2 MW/m^2, $q_{(,intra-ELM)}$ ≈6 MW/m^2, f_{ELM} ≈40 Hz. Various DiMES and sample geometries were used to achieve FPP relevant heat/particle fluxes, including samples angled 10-15° towards the incident plasma flux and heated DiMES up to 500 °C. Experiments revealed superior surface morphology (low surface defects, high density), compositional stability, thermal response, and crack resistance compared to PFMs previously tested at DIII-D.
The first exposure of liquid Li CPS in a tokamak successfully demonstrated uniform emission of Li vapor and suppression of Li droplets in H-mode with the sample pre-heated to 350 °C, while without pre-heating droplet ejection was observed. Dispersoid-strengthened W with 1 wt% TaC, TiC, and ZrC exposed to H-mode using 10° angled samples showed cracking and dispersoid ejection for all varieties except TiC, providing a clear down-selection. UHTC materials TiB2 and ZrB2 showed minimal degradation under L-mode exposure. SiC fiber composites showed microscopic cracking and arcing along edges, while CVD SiC remained pristine. Thermal plasma spray W and SiC demonstrated granular material ejection during ELMs in H-mode but survived with no macroscopic delamination. Additional W-based alloys were stress tested in H mode, including Ni-based W Heavy Alloys (WHAs), WfSiCf/W, and functionally-graded W/SiC. 10° angled WHAs displayed edge melting and cracking and heavy redeposition.

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